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FEB 25 2008

PATENT & TRADEMARK OFFICE

Attorney Docket No. AM-8893 Y1 U.S. Express Mail No.: EB 998981463 US

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

IN RE APPLICATION OF: Ki-Ho Baik et al.	§ GROUP ART UNIT: 1756
	§ (In parent case)
SERIAL NO.: 10/817,140	§
	§ EXAMINER: B.L. Raymond
RCE FILED: October 25, 2007	§ (In parent case)
	§
FOR: METHOD OF IMPROVING THE UNIFORMITY OF	§
A PATTERNED RESIST ON A PHOTOMASK	§ Attorney Docket No.:
	§ AM-8893 Y1

Date: February 25, 2008

NOTICE OF FILED RESPONSE TO DECISION DISMISSING PETITION
TRANSMITTAL LETTER

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

A Declaration of Prior Invention Under 37 CFR § 1.131 was submitted on October 25, 2007. Accompanying the Declaration was a Petition In Support of Declaration of Prior Invention Under 37 CFR § 1.131 for acceptance of the Declaration without signatures of two inventors who could not be located at that time.

The Petition was dismissed by Petitions Attorney Grant on January 3, 2008. Applicants' attorney has submitted a Response to Decision Dismissing Petition, which Response was filed at Mail Stop Petition on February 25, 2008. A copy of the Response to Decision Dismissing Petition and accompanying documentation is enclosed.

CERTIFICATE OF MAILING UNDER 37 CFR § 1.10

I hereby certify that this paper is being deposited with the U.S. Postal Service on the date shown below with sufficient postage as U.S. EXPRESS MAIL NO. EB 998981707 US in an envelope addressed to: Mail Stop Amendment, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Date: February 25, 2008

Shirley L. Church

Shirley L. Church, Reg. No. 31,858

As a result of a second effort to obtain two missing signatures of the five inventors, applicants' attorney was able to obtain the signature of Inventor Homer Lem on the Declaration of Prior Invention Under 37 CFR § 1.131. The Declaration of Prior Invention Under 37 CFR § 1.131 with Homer Lems' signature is submitted herewith.

In the event that the Response to Decision Dismissing Petition filed February 25, 2008 is granted, the Examiner is hereby requested to accept the Declaration of Prior Invention Under 37 CFR § 1.131 by the inventors. The Examiner is then requested to withdraw the citation of Kirkpatrick (U.S. Patent Application 2006/0084229) in view of Itoh (U.S. Patent Application 2004/0058279) against the claims currently pending in the application.

Applicants do not believe that any fee is due in connection with the filing of this Notice of Filed Response to Decision Dismissing Petition. Applicants do not believe any fee is due in connection with the filing of the copy of the Declaration of Prior Invention executed by Inventor Homer Lem. However, in the event any fees are due, the Commissioner is hereby authorized to charge any additional fees which may be due, and to credit any overpayment to Deposit Account No. 50-1512 of Shirley L. Church, Esq. of San Diego, California, in the amount of such fee.

This transmittal letter is submitted in duplicate for accounting purposes.

Respectfully Submitted,

Date: February 25, 2008

Shirley L. Church

Shirley L. Church
Registration No. 31,858
Attorney for Applicants
(858) 587-6633

Correspondence Address:
Customer No. 60767
Shirley L. Church, Esq.
P.O. Box 81146
San Diego, CA 92138

Attorney Docket No. AM-8893 U.S. Express Mail No.: EB 796042834 US

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

IN RE APPLICATION OF: Ki-Ho Baik et al.	§ GROUP ART UNIT: 1756
	§
SERIAL NO.: 10/817,140	§
	§ EXAMINER: B.L. Raymond
FILED: April 2, 2004	§
	§
FOR: METHOD OF IMPROVING THE UNIFORMITY OF A PATTERNED RESIST ON A PHOTOMASK	§ Attorney Docket No.: AM-8893

Date: February 25, 2008

DECLARATION OF PRIOR INVENTION UNDER 37 CFR § 1.131

Mail Stop Petition
Hon. Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

This Declaration is to be combined with the Declaration Under 37 CFR § 1.131 which was filed in response accompanies Response "B", which is in response to the Office Action mailed July 25, 2007.

Ki-Ho Baik, Mark A. Mueller, Stephen Osborne, Robert Dean, and Homer Lem are joint inventors of the invention claimed in U.S. Patent Application Serial No. 10/817,140. I, Homer Lem, declare that said invention was conceived and reduced to practice by the above-named inventors prior to January 6, 2004, which is the filing date of U.S. Patent Application Serial No. 10/752,885, which was published on December 30, 2004, as U.S. Publication No. 2004/0266113.

CERTIFICATE OF MAILING UNDER 37 CFR 1.10

I hereby certify that this paper and any documents said to accompany this paper are being deposited with the U.S. Postal Service on the date shown below with sufficient postage as U.S. EXPRESS MAIL NO. EB 450583747 US in an envelope addressed to : Mail Stop AF, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Date: February 25, 2008

Shirley L. Church

Shirley L. Church, Reg. No.31,858

In support of our Declaration, attached is a copy of the Invention Alert which preceded the present patent application. This Invention Alert was prepared by us and sent electronically to the docketing department of Applied Materials, Inc. on 11/21/2003. Subsequently, the Invention Alert was returned to us for signature, and signatures were obtained between December 17 and December 18, 2003. The signatures were witnessed on December 18, 2003, a Docket No. of 8893 was assigned, and the Invention Alert was scheduled to be sent out to an attorney for preparation of a patent application on that date.

Portions of the Invention Alert which pertain to conclusory dates of invention have been dedacted to protect the rights of the inventors.

We, the undersigned, each declare that all statements made herein are of his own knowledge true, and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both under Sec. 1001 of Title 18 of the United States Code, and that such willful false statements and the like may jeopardize the validity of the application or any patent issued thereon.

1) ____________ ____________________
Ki-Ho Baik, Co-inventor

2) ____________ ____________________
Mark A. Mueller, Co-inventor

3) ____________ ____________________
Stephen Osborne, Co-inventor

4) ____________ ____________________
Robert Dean, Co-inventor

5) Jan. 22, 2008 Homer Lem
Homer Lem, Co-inventor

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

IN RE APPLICATION OF: Ki-Ho Baik et al.	§ GROUP ART UNIT: 1756 § (In parent case)
SERIAL NO.: 10/817,140	§ EXAMINER: B.L. Raymond § (In parent case)
RCE FILED: October 25, 2007	§
FOR: METHOD OF IMPROVING THE UNIFORMITY OF A PATTERNED RESIST ON A PHOTOMASK	§ Attorney Docket No.: § AM-8893 Y1

Date: February 25, 2008

RESPONSE TO DECISION ON PETITION IN SUPPORT OF DECLARATION OF PRIOR INVENTION UNDER 37 CFR § 1.131 TRANSMITTAL LETTER

Mail Stop PETITION
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Transmitted herewith is applicants' Response to Decision Dismissing Petition, including Exhibit "A" - Declaration of Line Gauthier Under MPEP 409.03(d); Exhibit "B" - internet search results; Exhibit "C" - letter and accompanying documents sent to Inventor Stephen Osborne requesting signature; Exhibit "D" - statement from U.S. Post Office Delivery personnel; and a copy of the Declaration of Prior Invention Under 37 CFR § 1.131 with Inventor Homer Lem's signature. For reference purposes, applicants have also enclosed a copy of the Petition in

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CERTIFICATE OF MAILING UNDER 37 CFR § 1.10

I hereby certify that this paper is being deposited with the U.S. Postal Service on the date shown below with sufficient postage as U.S. EXPRESS MAIL NO. EB 998981707 US in an envelope addressed to: Mail Stop Petition, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Date: February 25, 2008

Shirley L. Church
Shirley L. Church, Reg. No. 31,858

Support of Declaration of Prior Invention Under 37 CFR§ 1.131 including a copy of the original Invention Alert signed by all five of the inventors.

Applicants do not believe that any additional fee is due in connection with the filing of this Response to Decision Dismissing Petition. However, in the event any fees are due, the Commissioner is hereby authorized to charge any additional fees which may be due, and to credit any overpayment to Deposit Account No. 50-1512 of Shirley L. Church, Esq. of San Diego, California, in the amount of such fee.

This transmittal letter is submitted in duplicate for accounting purposes.

Respectfully Submitted,

Date: February 25, 2008

Shirley L. Church

Shirley L. Church
Registration No. 31,858
Attorney for Applicants
(858) 587-6633

Correspondence Address:
Shirley L. Church, Esq.
P.O. Box 81146
San Diego, CA 92138

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

IN RE APPLICATION OF: Ki-Ho Baik et al. § GROUP ART UNIT: 1756 (In parent case)

SERIAL NO.: 10/817,140 § EXAMINER: B.L. Raymond (In parent case)

RCE FILED: October 25, 2007

FOR: METHOD OF IMPROVING THE UNIFORMITY OF A PATTERNED RESIST ON A PHOTOMASK § Attorney Docket No.: AM-8893 Y1

Date: February 25, 2008

RESPONSE TO DECISION DISMISSING PETITION MAILED JANUARY 3, 2008

Mail Stop PETITION
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

1. This Response to Decision Dismissing Petition is in reply to the Decision on Petition mailed January 3, 2008.

2. This Response is made to obtain acceptance of the Petition In Support of Declaration of Prior Invention Under 37 CFR § 1.131. The Petition accompanied Response "B", which was made in reply to the Office Action mailed July 25, 2007. Petition Attorney Grant informed applicants' attorney in her Decision On Petition, that the Petition was dismissed because the

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CERTIFICATE OF MAILING UNDER 37 CFR 1.10

I hereby certify that this paper and any documents said to accompany this paper are being deposited with the U.S. Postal Service on the date shown below with sufficient postage as U.S. EXPRESS MAIL NO. EB 998981707 US in an envelope addressed to : Mail Stop PETITION, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Date: February 25, 2008

Shirley L. Church

Shirley L. Church, Reg. No.31,858

Petition Examiner concluded that Petitioner had failed to show adequate proof that a diligent effort was made to reach or locate inventors Osborne and Lem.

3. Applicants' attorney, with the exercise of diligent effort, has located inventor Homer Lem who has signed the Declaration Of Prior Invention Under 37 CFR § 1.131. Applicants are enclosing a copy of the Declaration executed by inventor Lem.

4. Applicants have now found four of the five inventors, each of whom has signed the Declaration Of Prior Invention Under 37 CFR § 1.131.

5. On January 17, 2008, an assistant of applicant's attorney, Line Gauthier, searched for information regarding the fifth inventor, Stephen Osborne. Inventor Osborne no longer works for Applied Materials, Inc. and left without giving a forwarding address to his employer. Applicants used the Internet search engines Google and www.peoplelookup.com and found numerous persons named Stephen Osborne scattered across the United States. Applicants telephoned the Phone Operator asking for phone numbers relating to the name Stephen Osborne in the city where Inventor Osborne was last known to reside, Hayward, California, and its vicinity. The Phone Operator offered three phone numbers, which applicants dialed. All three phone numbers were wrong numbers.

6. Further, on January 17, 2008, applicants sent a letter to Inventor Osborne at his last known address, via Express Mail, requesting a delivery signature, and including a request letter, the Declaration of Prior Invention Under 37 CFR § 1.131, the Invention Alert Form, a copy of the application as filed, and a self-addressed, stamped envelope.

7. On February 6, 2008, the U.S. Postal Service returned the unopened package to applicants' attorney stating that Stephen Osborne had moved leaving no forwarding address.

8. On February 12, 2008, we extended our research outside of the Hayward area and requested assistance from the Phone Operator to find a Stephen P. Osborne in Woodland Hills, California; Middleton, Wisconsin; Santa Monica, California; and Santa Clara, California. There were no such listings.

9. Applicants are enclosing a copy of the internet search results (Exhibit "B"), a copy of the letter to Inventor Osborne and accompanying documents (Exhibit "C"), and a copy of the returned envelope with the U.S. Postal Service statement that Inventor Osborne moved without leaving a forwarding address (Exhibit "D").

10. Applicants believe that the enclosed documents are adequate proof that a diligent effort was made to locate Inventor Osborne, who left his place of employment and residence without leaving a forwarding address either to his employer or with the U.S. Postal Services. A Statement Of Facts that fully describes the exact facts which applicants are relying upon to establish that a diligent effort was made to locate Inventor Osborne is also enclosed (Exhibit "A)". The Statement is signed by attorney's assistant, Line Gauthier, who performed the research and prepared the letter sent to Inventor Osborne, and who, thus, has first hand knowledge of the facts recited therein.

11. Applicants have obtained the signatures of four of the five inventors on the Declaration of Prior Invention Under 37 CFR § 1.131; combined with this is the fact that all five of the inventors executed an Invention Alert describing the invention prior to the date at issue (and a copy of that Invention Alert has been submitted as part of the Declaration of Prior Invention). The Office of Petitions is respectfully requested to grant the Petition In Support of Declaration of Prior Invention Under 37 CFR § 1.131 in Application Serial No. 10/817,140. This Petition requests the Declaration of Prior Invention Under 37 CFR § 1.131 be accepted without the signature of one inventor (Stephen Osborne). Granting of the Petition is necessary so that

inventors' Declaration of Prior Invention will be accepted by Examiner B.L. Raymond in pending Application Serial No. 10/817,140.

12. This Petition is accompanied by the fee required under 37 CFR § 1.17(f).

Respectfully submitted,

Date: February 25, 2008

Shirley L. Church
Shirley L. Church
Registration No. 31,858
Attorney for Applicants
(858) 587-6633

Correspondence Address:
Customer No. 60767
Shirley L. Church, Esq.
P.O. Box 81146
San Diego, California 92138

Attorney Docket No.: AM-8893 Y1 U.S. Express Mail No. EB 998981707 US

OIPE FEB 25 2008 PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

IN RE APPLICATION OF: Ki-Ho Baik, et al.	§ GROUP ART UNIT: 1763
SERIAL NO.: 10/817,140	§ EXAMINER: B.L. Raymond
FILED: April 2, 2004	§
FOR: METHOD OF IMPROVING THE UNIFORMITY OF A PATTERNED RESIST ON A PHOTOMASK	§ ATTORNEY DOCKET NO.: AM-8893 Y1

Date: February 25, 2008

DECLARATION OF LINE GAUTHIER UNDER MPEP 409.03(d)
EXHIBIT "A"

Mail Stop PETITION
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

This Declaration under MPEP 409.03(d) accompanies a response to the Decision Dismissing Petition mailed January 3, 2008.

I, Line Gauthier, an assistant to Shirley L. Church, Esq., having firsthand knowledge of the facts recited herein, declare that the statements below are the exact facts showing the diligent effort I exercised to locate Inventor Stephen P. Osborne, an inventor of the invention claimed in U.S. Patent Application Serial No. 10/817,140, who no longer works for Applied Materials, Inc. and who has left no forwarding address with his last known employer, Applied Materials, Inc. nor with the U.S. Postal Services at his last known address.

CERTIFICATE OF MAILING UNDER 37 CFR § 1.10

I hereby certify that this paper and any documents said to accompany this paper are being deposited with the U.S. Postal Service on the date shown below with sufficient postage as U.S. EXPRESS MAIL NO. EB 998981707 US in an envelope addressed to: Mail Stop Patent Petition, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Date: February 25, 2008

Shirley L. Church

Shirley L. Church, Reg. No.31,858

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1. Inventor Osborne's last known address is 1128 "D" Street, Hayward, CA 94541.

2. On January 17, 2008, I searched the name Stephen Osborne in the Google search engine and found www.peoplelookup.com, which listed a large number of Stephen P. Osborne in several cities, in several states, thus rendering the search difficult. A copy of the search result is enclosed (Exhibit "B").

3. I called the Phone Operator and asked if a phone number was available for a Stephen P. Osborne in Hayward or near Hayward, California. The operator had only one listed number for Stephen P. Osborne in Hayward and two more in Santa Clara and Valencia. I called the number in Hayward but was told this was the wrong Stephen Osborne.

4. I called the other two phone numbers in Santa Clara and Valencia and was told they were wrong numbers.

5. In order to extend the scope of my search, I called the Phone Operator for assistance in finding listings for Stephen P. Osborne in Canyon Country, California; Woodland Hills, California; Middleton, Wisconsin; Santa Monica, California; and Santa Clara, California. There were no such listings.

6. On January 17, 2008, I sent a letter to Mr. Osborne at his last known address, via Express Mail, requesting a signature at delivery. Copies of the letter, the Declaration of Prior Invention Under 37 CFR § 1.131, the Invention Alert Form and application as filed are enclosed, self-addressed, stamped return envelope are enclosed (Exhibit "C").

7. On February 6, 2008, the United States Post Service returned the package to us indicating that Stephen Osborne had moved without leaving a forwarding address. A copy of the returned envelope showing the statement from the U.S. Post Service delivery person is also enclosed (Exhibit "D).

8. On February 12, 2008, I extended my research outside of the Hayward area and requested assistance from the Phone Operator to find a Stephen P. Osborne in Woodland Hills, California; Middleton, Wisconsin; Santa Monica, California; and Santa Clara, California. There were no such listings.

9. I have no telephone number for Stephen P. Osborne and no current address after having made the above-described effort to locate Stephen P. Osborne.

2/14/2008
Date:

Line Gauthier

Attorney Docket No. AM-8893 Y1 U.S. Express Mail No.: EB 998981707 US

IN RE APPLICATION OF: Ki-Ho Baik, et al.	§ GROUP ART UNIT: 1763
SERIAL NO.: 10/817,140	§ EXAMINER: B.L. Raymond
FILED: April 2, 2004	§
FOR: METHOD OF IMPROVING THE UNIFORMITY OF A PATTERNED RESIST ON A PHOTOMASK	§ ATTORNEY DOCKET NO.: AM-8893 Y1

EXHIBIT "B"

WWW.PEOPLELOOKUP.COM SEARCH RESULTS

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Login | My Account
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People Search | Reverse Phone | Background Check | Cell Phone ID | Other Services

PEOPLE LOOKUP RESULTS

41 People found that match **Stephen Osborne** .

Search Again >>

Click on the **Name** or **View Details** link for more info.

✔ = Available Information

See Details on All 41 People!

	NAME	AGE	PREVIOUS CITIES	DOB	PHONE	ADDRESS	RELATIVES
1	STEPHEN P OSBORNE Get More Info	39	PAHRUMP, NV YUMA, AZ TUCSON, AZ	✔	✔	✔	STEVE P OSBORNE VIRGINIA C OSBORNE MARK W OSBORNE WILLIAM G OSBORNE STEVEN J OSBORNE
2	STEPHEN PHILIP OSBORNE Get More Info	54	HAYWARD, CA CANYON COUNTRY, CA WOODLAND HILLS, CA MIDDLETON, WI SANTA MONICA, CA	✔	✔	✔	CYNTHIA CROSBY OSBORNE
3	STEPHEN P OSBORNE Get More Info	34	OCALA, FL	✔	✔	✔	STEVEN P OSBORNE
4	STEPHEN PAUL OSBORNE Get More Info	49	GARLAND, TX FORNEY, TX	✔	✔	✔	THERESA OSBORNE AMIE OSBORNE BLAKE OSBORNE WUT T OSBORNE ALETA JOYCE OSBORNE JOYCE CHANEY OSBORNE JERRY WILLIAM OSBORNE
5	STEPHEN P OSBORNE Get More Info	34	OCALA, FL	✔	✔	✔	STEVEN P OSBORNE JAIME OSBORNE
6	STEPHEN P OSBORNE Get More Info	49	MILAN, TN MEDINA, TN	✔	✔	✔	
7	STEPHEN P OSBORNE Get More Info	51	CHULA VISTA, CA BONITA, CA SAN DIEGO, CA	✔	✔	✔	BERIT OSBORNE MAXINE L OSBORNE DIANE APRIL OSBORNE LINDA N OSBORNE
8	STEPHEN PATRICK OSBORNE Get More Info	43	DELAND, FL	✔	✔	✔	STEVE LEE OSBORNE SARA L OSBORNE
9	STEPHEN P OSBORNE Get More Info	85	PITTSBURGH, PA	-	✔	✔	MARY J OSBORNE STEVE OSBORNE
10	STEPHEN P OSBORNE Get More Info	40	BOCA RATON, FL NEWARK VALLEY, NY SAINT PETERSBURG, FL TAMPA, FL OLDSMAR, FL PINELLAS PARK, FL	✔	✔	✔	STEVEN P OSBORNE
	NAME	AGE	PREVIOUS CITIES	DOB	PHONE	ADDRESS	RELATIVES

	NAME	AGE	PREVIOUS CITIES	DOB	PHONE	ADDRESS	RELATIVES
11	STEPHEN PATRICK OSBORNE Get More Info	58	NEWHALL, CA	✔	✔	✔	RYAN OSBORNE DELFINA OSBORNE CARY F OSBORNE
12	STEPHEN P OSBORNE Get More Info	58	VALENCIA, CA	✔	✔	✔	D OSBORNE STEVE OSBORNE
13	STEPHEN P OSBORNE Get More Info	34	OCALA, FL	✔	✔	✔	
14	STEPHEN P OSBORNE Get More Info	51	DELAND, FL	✔	✔	✔	SARA L OSBORNE
15	STEPHEN P OSBORNE Get More Info	49	MESQUITE, TX	✔	✔	✔	THERESA M OSBORNE
16	STEPHEN P OSBORNE Get More Info	-	BUTTE, MT	-	✔	✔	
17	STEPHEN P OSBORNE Get More Info	-	BUTTE, MT	-	✔	✔	JOHN OSBORNE BETTY OSBORNE JANET L OSBORNE SHARON MAE OSBORNE STEVE P OSBORNE ELIZABETH OSBORNE WILLIAM JOHN OSBORNE
18	STEPHEN P OSBORNE Get More Info	23	RODMAN, NY	✔	✔	✔	CAROLYN H OSBORNE DANIEL CAROLYN OSBORNE
19	STEPHEN P OSBORNE Get More Info	34	OCALA, FL	✔	-	✔	STEVEN P OSBORNE
20	STEPHEN P OSBORNE Get More Info	34	OCALA, FL	✔	-	✔	STEVEN P OSBORNE
	NAME	AGE	PREVIOUS CITIES	DOB	PHONE	ADDRESS	RELATIVES
21	STEPHEN P OSBORNE Get More Info	34	OCALA, FL	✔	✔	✔	IRENE C OSBORNE NELLIE I OSBORNE YVONNE O OSBORNE
22	STEPHEN P OSBORNE Get More Info	85	PITTSBURGH, PA	-	-	✔	MARY J OSBORNE JAMES W OSBORNE
23	STEPHEN P OSBORNE Get More Info	36	LYNN, MA	✔	-	✔	STEVE P OSBORNE
24	STEPHEN P OSBORNE Get More Info	58	PHOENIX, AZ	✔	-	✔	JOHN S OSBORNE
25	STEPHEN P OSBORNE Get More Info	34	OCALA, FL	✔	-	✔	

	NAME	AGE	PREVIOUS CITIES	DOB	PHONE	ADDRESS	RELATIVES
26	STEPHEN P OSBORNE Get More Info	59	CANYON COUNTRY, CA	-	-	✔	
27	STEPHEN P OSBORNE Get More Info	55	HOUSTON, TX	✔	-	✔	
28	STEPHEN P OSBORNE Get More Info	-	NORMAN, OK	-	✔	✔	
29	STEPHEN P OSBORNE Get More Info	46	DENVER, CO	-	-	✔	
30	STEPHEN P OSBORNE Get More Info	51	SAN DIEGO, CA	✔	-	✔	
	NAME	AGE	PREVIOUS CITIES	DOB	PHONE	ADDRESS	RELATIVES
31	STEPHEN P OSBORNE Get More Info	-	ENDICOTT, NY	-	✔	✔	
32	STEPHEN P OSBORNE Get More Info	55	SANTA CLARA, CA	✔	-	✔	
33	STEPHEN P OSBORNE Get More Info	-	CHULA VISTA, CA	-	-	✔	
34	STEPHEN P OSBORNE Get More Info	-	BUTTE, MT	-	-	✔	
35	STEPHEN P OSBORNE Get More Info	-	BUTTE, MT	-	-	✔	
36	STEPHEN P OSBORNE Get More Info	-	YUMA, AZ	-	✔	✔	STEVE P OSBORNE
37	STEPHEN P OSBORNE Get More Info	51	CHULA VISTA, CA	✔	-	✔	
38	STEPHEN P OSBORNE Get More Info	-	PINELLAS PARK, FL	-	-	✔	
39	STEPHEN P OSBORNE Get More Info	-	PACOIMA, CA	-	-	✔	
40	STEPHEN P OSBORNE Get More Info	31	IRWIN, PA	✔	-	✔	
	NAME	AGE	PREVIOUS CITIES	DOB	PHONE	ADDRESS	RELATIVES

41	STEPHEN P OSBORNE Get More Info	-	SANTA MONICA, CA	-	-	✔

RELATED PEOPLE SEARCHES

- STEFAN OSBORNE
- STEPHAN OSBORNE
- STEVAN OSBORNE
- STEVE OSBORNE
- STEVEN OSBORNE
- STEVIE OSBORNE
- S OSBORNE

IN RE APPLICATION OF: Ki-Ho Baik, et al.

SERIAL NO.: 10/817,140

FILED: April 2, 2004

FOR: METHOD OF IMPROVING THE UNIFORMITY OF A PATTERNED RESIST ON A PHOTOMASK

§ GROUP ART UNIT: 1763
§
§
§ EXAMINER: B.L. Raymond
§
§
§ ATTORNEY DOCKET NO.:
§ AM-8893 Y1

EXHIBIT "C"

LETTER SENT TO INVENTOR OSBORNE

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er

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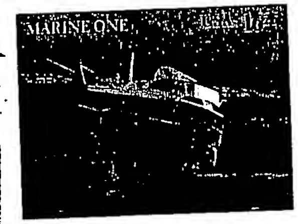

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	Military ☐ 2nd Day ☐ 3rd Day	Total Postage & Fees $
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Delivery Attempt Mo. Day	Time ☐ AM ☐ PM	Employee Signature
Delivery Date Mo. Day	Time ☐ AM ☐ PM	Employee Signature

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NO DELIVERY ☐ Weekend ☐ Holiday

Shirley L. Church
Mailer Signature

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January 18, 2008

Via Express Mail

Mr. Stephen Osborne
1228 D Street
Hayward, CA 94541

RE: U.S. Patent Application No.: 10/817,140
For: "Method of Improving the Uniformity of a Patterned Resist on Photomask"
Filed: April 2, 2004
Our Ref. No.: AM-8893 Y1

Dear Mr. Osborne:

We are filing a Request for Continued Examination of the above-referenced application of which you are an inventor. We are enclosing a copy of a *Declaration of Prior Invention Under 37 CFR § 1.131* for your signature. We need your signature to proceed with the application.

Also enclosed are a copy of the patent application as filed and a copy of the invention alert showing critical dates for your reference. A self-addressed envelope is included for the return of the signed Declaration of Prior Invention

As you may know, inventors must **sign and date** the Declaration to be accepted by the PTO. Also, all hand-written changes must be initialed by the inventor making such changes. Please return the signed and dated Declaration to us by **February 1, 2008** so that we may file the document with the U.S. Patent Office in a timely manner.

We thank you so much for your assistance in this matter. Please do not hesitate to contact us if you have any questions or comments.

With my best regards,

By: Shirley L. Church
Shirley L. Church, Esq.

SLC:lsg
Enclosures

cc: Maureen Walstra, Patent Administrator (via email only)
patent_office@amat.com (via email only)

Attorney Docket No. AM-8893 BE U.S. Express Mail No.: EB 796042834 US

FEB 25 2008

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

IN RE APPLICATION OF: Ki-Ho Baik et al.	§ GROUP ART UNIT: 1756
	§
SERIAL NO.: 10/817,140	§
	§ EXAMINER: B.L. Raymond
FILED: April 2, 2004	§
	§
FOR: METHOD OF IMPROVING THE UNIFORMITY OF A PATTERNED RESIST ON A PHOTOMASK	§
	§ Attorney Docket No.:
	§ AM-8893

Date: ____________, 2008

DECLARATION OF PRIOR INVENTION UNDER 37 CFR § 1.131

Mail Stop AF
Hon. Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

This Declaration under 37 CFR § 1.131 accompanies Response "B", which is in response to the Office Action mailed July 25, 2007.

We, Ki-Ho Baik, Mark A. Mueller, Stephen Osborne, Robert Dean, and Homer Lem hereby declare that we are joint inventors of the invention claimed in U.S. Patent Application Serial No. 10/817,140. We further declare that said invention was conceived and reduced to practice by us prior to January 6, 2004, which is the filing date of U.S. Patent Application Serial No. 10/752,885, which was published on December 30, 2004, as U.S. Publication No. 2004/0266113.

CERTIFICATE OF MAILING UNDER 37 CFR 1.10

I hereby certify that this paper and any documents said to accompany this paper are being deposited with the U.S. Postal Service on the date shown below with sufficient postage as U.S. EXPRESS MAIL NO. EB 450583747 US in an envelope addressed to : Mail Stop AF, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Date: ________________, 2008

____
Shirley L. Church, Reg. No.31,858

In support of our Declaration, attached is a copy of the Invention Alert which preceded the present patent application. This Invention Alert was prepared by us and sent electronically to the docketing department of Applied Materials, Inc. on 11/21/2003. Subsequently, the Invention Alert was returned to us for signature, and signatures were obtained between December 17 and December 18, 2003. The signatures were witnessed on December 18, 2003, a Docket No. of 8893 was assigned, and the Invention Alert was scheduled to be sent out to an attorney for preparation of a patent application on that date.

Portions of the Invention Alert which pertain to conclusory dates of invention have been dedacted to protect the rights of the inventors.

We, the undersigned, each declare that all statements made herein are of his own knowledge true, and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both under Sec. 1001 of Title 18 of the United States Code, and that such willful false statements and the like may jeopardize the validity of the application or any patent issued thereon.

1) ________________ ________________________________
Ki-Ho Baik, Co-inventor

2) ________________ ________________________________
Mark A. Mueller, Co-inventor

3) ____________, 2008 ________________________________
Stephen Osborne, Co-inventor

4) ________________ ________________________________
Robert Dean, Co-inventor

5) ________________ ________________________________
Homer Lem, Co-inventor

ENTERED

ALERT NO: 8893

INVENTION ALERT FORM

Date: 11/21/2003

TO: Gaile Bailey M/S 2061/Extension 32724

CIRCLE ONLY ONE FROM TOP ROW(REQUIRED FIELD):-

MASK/ETEC

EPI/ SUBSTRATE 3365	WCVD / 2492	CMP 1399	METAL 0881	CPS 0676	CORE ENG 0793	COPPER 2492	AKT	ATD 1301	APD	FBT 3037	HDPCVD 0281	CONDUCTIVE 1077	MDR	ETEC
OXD 3365	Ti/TiN 2492		SILICON 0916	SMO/ GAS 1649	EPS 2590	ALUMINUM 2492	EBT		CDSEM	MDR/ DSI 3047	BCVD 0166	PARAMETRIC 1755	MMCS/ APC	RT
LPCVD 3365	ALD		DIELECTRIC/ RIE 0521	SMO/ PUMP 1651	DT 2492	LINER/ BARRIER 2492			WF		LOW K 2445	ORION/CON 2471	MMCS/ Modular Controller 3413	
UCM 3365			DIELECTRIC/ ICP 0521	EPIC 2442		Copper Plating(ECP) 2492			DRSEM		ELK 2445	ORION/PAR 2471	SmartSys	
WET CLEAN 3365			CONDUCTOR 0894	SCALPEL					GEMI				PDC-DSI 3396	
PMD 3365			CHAMBER TECH 0894	CONSILIUM 2199					ICT					
OTHER 3365			CORE TECH 1245	ECOM					EBI					
						COPPER					Dual Dam			

1. Title of Invention (please print clearly): **Vacuum Treatment for Improvement of Uniformity of Patterned Resist on a Photomask and Wafer**

2. Inventors-Names only-(please print clearly and provide complete information at Section 9.)

   Ki-Ho Baik, Mark Mueller, Steve Osborne, Robert Dean, Homer Lem

OIPE
FEB 25 2008
PATENT & TRADEMARK OFFICE

Please use separate attachments for any answers that don't fit on the form, especially for questions 3-8. If the answer to a question is "NONE", please write "NONE" rather than leaving the answer blank.

3. Earliest dates and model names of all Applied products incorporating the invention which have been offered for sale or are expected to be offered for sale:

Mebes eXara, electron beam photomask writer,

RSB, electron beam photomask writer,

Tetra1, photomask etcher,

Tetra2, photomask etcher,

4. If the invention has been demonstrated or described to persons other than Applied employees, for each disclosure please provide the earliest date, name of company, a brief description of what was disclosed and the purpose of the disclosure. Attach a copy of any related non-disclosure agreements:

NOT described outside Applied Materials, not yet disclosed.

5. If future disclosures like those in Question #4 are expected to occur within the next 12 months, please provide the anticipated date, type of information to be disclosed, and purpose of the disclosure:
NONE [ ]

This invention would be most useful for ETEC to meet its technical specifications and commitments at IBM, where an RSB is being evaluated and compared to a competing product. Therefore it would be in Applied Materials' business interests to disclose this invention to IBM as soon as possible, in order to improve the ETEC-RSB product performance and gain a competitive advantage.

Preliminary data shows an improvement in resist local CD uniformity as a result of vacuum treatment. CD uniformity improvement in resist is between zero and 1 nm 3sigma, which is significant.

This invention is expected to be of significant interest to the photomask user community. Thus publication, after patent filing protection of IP, would serve Applied Materials' interests in advertising lithographic patterning capabilities.

6. Describe any other known designs or processes, whether actually implemented or merely proposed in a publication, which could be considered similar to your invention or which constitute the state-of-the-art improved upon by your invention: If described in a publication, attach a copy of same or provide a citation.

No known publications describe anything similar to this invention.

A broad search on the US Patent Office website (USPTO.com) scanning for the phrase "resist AND vacuum AND (semiconductor OR lithography OR photomask)" in claims turned up no previous patent which has any similarity to the invention proposed here. There are no reported applications of vacuum processing which claim or report what we are listing below as a novel and non-obvious feature.

The state-of-the-art electron beam photomask processing sequence is summarized:

1. Photomask is coated with resist, post-~~exposure~~ application baked (PAB), and exposed (electron beam or

laser used for creating a pattern onto the photomask resist).

2. The photomask is post-exposure baked (PEB) and developed, which removes the unpatterned resist from the plate.

3. The photomask is then etched, whereby the resist pattern is transferred into an underlying chrome layer. Additional etching may be required for phase-shift masks (PSM).

7. List each feature of the invention which you consider novel and non-obvious. Describe the advantages of each novel feature in comparison with the state-of-the-art approaches which are most similar to your invention:

Novel and Non-Obvious Features:

1) Use of a **post-develop, pre-etch vacuum processing step to reduce variation in critical dimensions on photomasks.** The advantage of such a processing step is of enormous benefit to photomask manufacturers. By reducing variation in critical dimensions, the quality of the photomask is improved.

   State of the art: No specific vacuum treatment of photomask. The photomask is simply developed, air exposed (and possibly measured in a CD-SEM to get resist CD information), and then the chrome is etched.

2) Use of **vacuum to alter the composition and dimensions of resist features on a photomask.** By applying a vacuum to a photomask (or wafer) for about 20 minutes, water vapor and solvent are desorbed by the surface of the resist. This may enable surface tension (or other mechanisms not yet studied in complete detail) to minimize roughness on the sidewall of a resist feature, which reduces line edge roughness (LER) and also reduces CD variation. Vacuum processing affects the mean CD by only a few nanometers.

   State of the art: One commonly applied means of altering resist dimensions on a photomask (or wafer) is the use of a "descum" oxygen plasma step. This basically burns away a fixed amount of resist, which unfortunately reduces the resist dimensions by at least 30nm, but also may also help to smoothen line edges. Descum treatment is not applicable to small feature lithography, since this step consumes a significant amount of lateral resist.

3) Application **of vacuum treatment to reduce Line Edge Roughness (LER) on resist lines on a photomask (patterned by either electron beam or laser).**

   State of the art: Descum (see #3 **above).**

4) **Application of vacuum to a photomask plate in a photomask etching chamber in which chamber walls and dome are heated, allowing the resist on the photomask to warm to a temperature between 30 degrees C and 55 degrees C, which enables the desorption from the surface of the resist of water vapor, solvents, and materials absorbed onto the surface from the develop process step and other previous steps.** In particular, the Applied Materials Tetra etching system is used for this vacuum treatment. Photomasks are placed into a chamber for 20 minutes of vacuum time, where the 55 degree chamber wall and 70 degree dome radiate heat onto the photomask plate. Longer times do not provide any improvement in desorption. The "curve" of resist change is observed to flatten out at 20 minutes.

5) **Application of a vacuum treatment to a photomask (or wafer) after electron beam exposure (or** laser or other **methods of resist exposure) to reduce critical dimension variation.**

Preliminary data from delayed removal of a photomask from the RSB electron beam writer has shown that CD uniformity may be slightly improved. A nine-hour delay time was utilized in this preliminary work. Delayed removal places the photomask in vacuum for a longer period, prior to air exposure and immediate Post-Exposure Bake. It is possible to perform this vacuum treatment in a Tetra (Applied Materials photomask etcher) chamber, where the vacuum treatment does not impact the RSB throughput. It is also possible to perform the vacuum treatment in other vacuum chambers.

6) **Generalization of #1 through 5 to include wafers and other substrates.** General application to wafers can improve the quality of lithography in the patterning of wafers. Specifically, this can be applied to all wafer lithographic processes where critical dimension control is required, for all wavelengths of light utilized in wafer lithography (G-line, i-line, KrF, ArF, 157) plus other methods used for patterning resist on wafers, such as e-beam, FIB, X-ray, and EUV. Line edge roughness is reduced, and critical dimension control is improved.

8. Describe the invention, preferably with reference to attached drawings:

The invention consists of an additional processing step in the standard "state of the art" sequence described above in Part 6. This is specifically a vacuum applied to the photomask between Step 2 and Step 3 (as noted above in Part 6). Proper timing of the vacuum allows for desorption of materials from the resist surface. Such desorption is found to slightly decrease the thickness of the resist layer. In addition, a slight shrinkage of pattern dimension is observed in the lateral (photomask plane) directions. Moreover, our data shows an improvement in Local CD Uniformity, in which crosses of a given fixed size are printed within a 1mm square, and then measured. Variations in local CD Uniformity can be attributed to a) various electron beam fluctuations during resist patterning and b) process-related line-edge roughness. The ETEC process has succeeded in drastically reducing the latter by creating a proprietary resist and fine-tuning all of the resist-related processing parameters. However, we believe at this time that vacuum processing is capable of further reduction in line-edge roughness, resulting in reduced Local CD Uniformity.

Two types of vacuum treatment are described above in the previous section. Vacuum treatment can be applied to a photomask immediately after exposure and before PEB (Post Exposure Bake). This enables acids within the resist to diffuse in such a way as to improve contrast and to reduce line edge roughness.

Another vacuum treatment is applied to the photomask after develop. In this second vacuum treatment, water vapor and solvents are desorbed from the surface of the patterned resist. In this case, the surface includes sidewalls and the top resist surface. By desorbing the volatile components, the resist loses material and that part of resist close to the surface is in tension. This surface tension may allow for the "pulling together" of the surface which may smooth out sidewall roughness. Since the tension does not apply to the bulk of the resist (deeper than within a few nanometers of the surface), lines and other features are not distorted.

ATTACH ADDITIONAL SHEETS TO DESCRIBE INVENTION AS NEEDED

Provide the following information for EACH inventor** REQUIRED FIELDS:

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Product Group:	ETEC	Dept #:	0667

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Product Group:	ETEC	Dept #:	0667

Inventor

Legal Name:		Employee #	Mail Stop
Work Phone		Fax No:	
Job Title:			
Citizenship:			
Home Address:			
Manager		Title:	
Div. Manager		Title:	
Product Group:		Dept #:	

10. Signature, date and PRINTED name of each inventor plus two witnesses who have read and understood this Invention Alert form:

Inventors:

Printed Name	Date	Signature
MARK MUELLER	12/17/03	Mark Mueller
Robert Dean	12/17/03	[illegible]
Ki Ho BAEK	12/17/03	[illegible]
Homer Lem	12/18/03	Homer Lem
STEPHEN OSBURNE	12/18/03	S. T. Osborne

Witness:

Printed Name	Date	Signature
DAMON M. COLE	12/18/03	Damon M. Cole
Allen R. Cook	12/18/03	Allen R. Cook

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[0001] METHOD OF IMPROVING THE UNIFORMITY OF A PATTERNED RESIST ON A PHOTOMASK

[0002] 1. Field of the Invention

[0003] In general, the present invention relates to a method of producing a photomask (reticle) for use in the semiconductor industry. In particular, the invention pertains to a method for improving the critical dimension (CD) uniformity of a pattern in a photoresist which is used to transfer the pattern to a reticle.

[0004] 2. Brief Description of the Background Art

[0005] Photoresists are used in microlithographic processes to produce patterned features required for device functioning in miniaturized electronic components, such as in the fabrication of semiconductor device structures. The miniaturized electronic device structure patterns are typically created using blanket radiation through a photomask to produce a pattern in a layer of photoresist material present on a semiconductor structure. There are instances, for specialized devices, where a pattern is directly written into a photoresist present on the semiconductor structure; however, due to the slow production speed of the direct write process, this is not commonly done.

[0006] A photomask or reticle which is used to enable rapid semiconductor device processing typically includes a thin layer of a radiation-blocking material (which is often a metal-containing material, such as a chrome-containing, molybdenum-containing, or tungsten-containing layer, for example) deposited on a glass or quartz plate. The thin layer of radiation-blocking material is patterned to contain a "hard copy" of the pattern to be recreated on the photoresist or photoresist / hard mask layer overlying a semiconductor structure. The patterning of the radiation-blocking layer of a reticle may be carried out using a number of different techniques. Due to the dimensional requirements of today's semiconductor structures, the pattern is typically generated using a direct write laser or e-beam to create a latent image in a photoresist for subsequent transfer to the radiation-

blocking layer.

[0007] The reticle manufacturing process generally includes the following steps, when the initial substrate used to form the reticle is a silicon oxide-containing base layer having a layer of a metal-containing (typically chrome) mask material applied thereover: An inorganic antireflective coating (ARC) or an organic ARC, or a combination of inorganic and organic ARC layers, may be applied over the surface of the chrome mask material. A photoresist layer is then applied over the antireflective coating. The photoresist is typically an organic material which is dissolved in a solvent. The solution of photoresist is typically spin coated onto the surface of the photomask fabrication structure. Some of the solvent is removed during the spin coating operation. Residual solvent is subsequently removed by another means, typically by baking the fabrication structure, including the photoresist layer. This step is commonly referred to as a "post-apply bake" or PAB. The photoresist is then exposed to radiation (imaged), to produce a pattern in the photoresist layer, typically by a direct write process when the pattern includes dimensions which are less than about 0.4 μm or less. After exposure, the substrate including the photoresist layer is baked again. The second baking is typically referred to as a "post-exposure bake" or PEB. The photoresist is then developed, either using a dry process or a wet process, to create the pattern having openings through the photoresist layer thickness. Once the photoresist is "patterned" so that the pattern openings extend through the photoresist layer to the upper surface of an ARC layer, or to a surface beneath an ARC layer, the pattern in the patterned photoresist is transferred through the chrome-based mask layer and any remaining layers overlying the chrome layer, for example, typically by dry etching.

[0008] As described above, preparation of a photomask / reticle is a complicated process involving a number of interrelated steps which affect the critical dimensions of a pattern produced in the reticle and the uniformity of the pattern critical dimensions across the surface area of the reticle. Various efforts have been made within the industry to improve the reliability of manufacturing processes by improving individual process steps; however, when a production process involves a number of interrelated process steps, alteration of an

individual process step may have an unexpected result on other interrelated process steps.

[0009] Commonly owned U.S. Patent No. 6,703,169, to Scott Fuller et al., issued March 9, 2004, and entitled "Method of Preparing Optically Imaged High Performance Photomasks", discloses a state-of-the-art method of fabricating a photomask using optical radiation in the form of a direct write continuous wave laser. The claimed method comprises a series of steps including: applying an organic antireflection coating over a metal-containing layer; applying a chemically-amplified positive tone or negative tone DUV photoresist over the organic antireflection coating, to provide a photoresist-coated photomask substrate; post-apply baking the DUV photoresist over a temperature ranging from about 105°C to about 115°C; exposing a surface of the DUV photoresist to radiation from the direct write continuous wave laser, to provide a patterned photoresist across the photomask substrate; and post-exposure baking the DUV photoresist over a temperature ranging from about 70°C to about 90°C. The post-apply bake process provides increased stability period for the photoresist-coated photomask substrate, where there is less than a 5 nm change in a 400 nm latent image critical dimension after a 6-hour time period. A combination of the post-apply bake process and the post-exposure bake process results in a uniform critical dimension of the patterned photoresist across the photomask substrate, where, for a 132-mm x 132-mm active area, a critical dimension uniformity is ≤ 10 nm at 400 nm. The disclosure of U.S. Patent No. 6,703,169 is hereby incorporated by reference in its entirety.

[0010] Commonly owned, co-pending U.S. Application Serial No. 10/768,919, of Christopher Dennis Bencher et al., filed January 30, 2004, and entitled "Reticle Fabrication Using a Removable Hard Mask", discloses a method of fabricating a reticle which provides improved critical dimension uniformity during fabrication of a reticle by minimizing the problem known as "photoresist pull-back", which commonly occurs during etching of a chrome (or other radiation-blocking layer) on a reticle substrate. According to the method disclosed by Bencher et al., pattern transfer to the radiation-blocking layer of the reticle substrate essentially depends upon transfer from a hard mask rather than from a photoresist.

In one embodiment, a hard mask material having anti-reflective properties is left on the surface of the chrome after etching of the chrome. Since the hard mask surface faces the surface of a photoresist on the semiconductor substrate which is patterned using the reticle, the presence of the proper anti-reflective properties in the hard mask can be used to reduce the amount of bounce-back of reflected radiation which occurs during blanket radiation imaging of the semiconductor photoresist through the reticle. In another embodiment, where a wet etch is used during fabrication of the reticle, the hard mask material (whether having anti-reflective properties or not) is removed to prevent contamination during the wet etch process. In this embodiment, when a plasma etchant used to remove the hard mask would also etch the reticle base substrate (which is typically quartz), a protective layer is applied to fill at least a portion of patterned openings through the chrome during removal of the hard mask. This prevents etching of the quartz at the bottom of the pattern openings during removal of the hard mask. The disclosure of U.S. Application Serial No. 10/768,919 is hereby incorporated by reference in its entirety.

[0011] As device dimensions become even smaller, further improvements in critical dimension uniformity of photomasks are needed. One commonly used means of improving photomask dimensional uniformity is by improving the dimensions of the patterned photoresist used to transfer the pattern to the photomask. The patterned photomask may be "descummed" using an oxygen plasma step, in which surface defects are removed from the photoresist pattern. Exposure to the oxygen plasma basically burns away a fixed amount of resist, which may help to smooth pattern line edges. Unfortunately, however, the descum oxygen plasma step typically reduces the resist dimensions by about 20 - 30 nm, making the descum process inapplicable to very small feature lithography.

[0012] It is readily apparent that it would be highly desirable to have a method of making a photomask where the uniformity of pattern critical dimensions is maintained across the entire surface of the photomask, even for features smaller than about 100 nm. To provide an improved photomask, it would be very advantageous to provide an improved patterned photoresist which can be used to transfer the pattern directly to the photomask, or to transfer

the pattern to a hard mask which is subsequently used to pattern the photomask.

[0013] SUMMARY OF THE INVENTION

[0014] We have discovered that application of a vacuum to a pattern irradiated (imaged) photoresist prior to development of the photoresist provides an improvement in critical dimension and uniformity in the developed photoresist. This improvement is translated into an improvement in the patterned photomask produced using the photoresist.

[0015] Typically, the application of vacuum is carried out prior to a post-exposure bake of the kind which is commonly performed on an imaged photoresist prior to development. Exposure of the photoresist on the photomask substrate to vacuum is performed for a period of time sufficient to allow the imaged pattern critical dimensions to reach equilibrium across the photoresist. The vacuum treatment process allows reaction-by-product, water vapor, and solvents, for example, to desorb from the surface of the resist, improving critical dimension uniformity across the surface of the photoresist on the photomask substrate.

[0016] Typically, exposure of the pattern-imaged photoresist to vacuum is performed at a substrate temperature within the range of about 18°C to about 60°C (more typically, within the range of about 18°C to about 40 °C), for a period of time within the range of about 10 minutes to about 70 hours (more typically, within the range of about 20 minutes to about 12 hours), at a process chamber pressure ranging from about 5 x 10^{-6} mTorr to about 5 mTorr. The pressure within the processing chamber during the vacuum treatment process may be limited by the capability of the particular apparatus in which the vacuum treatment process is performed. For example, when the vacuum treatment process is performed in an Applied Materials' _______________ e-beam direct-write apparatus following the pattern writing process, the process chamber pressure during the vacuum treatment process is typically about 1 x 10^{-5} mTorr. When the vacuum treatment process is performed in an Applied Materials' TETRA™ etch system, the process chamber pressure during the vacuum treatment process may vary between about _____ mTorr to about _____ mTorr, and was typically in the range of about 0.5 mTorr to about 1 mTorr during the

experimentation described herein.

[0017] The time period required for pattern critical dimensions to reach equilibrium across the photoresist will depend upon the photoresist layer composition, and a combination of the temperature of the substrate / photoresist during the vacuum treatment process and the pressure (vacuum) applied. The minimal time period required for vacuum treatment of the photoresist on the photomask substrate will be the time period which provides no substantial change in pattern critical dimensions upon continued exposure of the irradiated photoresist to the vacuum.

[0018] Typically, the higher the temperature, the less time is required for pattern critical dimensions to reach equilibrium. However, the temperature is limited by the general stability of the photoresist material, which will depend on the particular photoresist material used. Also, typically the lower the pressure in the process chamber, the less time is required for vacuum treatment at a given temperature; however, the pressure used must ensure that deformation of the pattern does not occur and that the integrity of the photoresist is preserved. The amount of time required will also depend upon the condition of the photoresist prior to the vacuum treatment process, which will depend upon the type of photoresist used, the solvents in the photoresist, and the length of time of the post-apply bake (PAB) process. With minimal experimentation, one skilled in the art will be able to integrate the vacuum treatment step into an existing process for photomask production.

[0019] We have also discovered that exposure of the patterned (developed) photoresist to vacuum after development results in an improvement in the line edge roughness of pattern openings that have been formed through the photoresist layer thickness. This second vacuum treatment process is typically performed at a substrate temperature within the range of about 20°C to about 60°C for a period of time within the range of about 10 minutes to about 60 minutes, at a process chamber pressure ranging from about 5 x 10^{-6} mTorr to about 5 mTorr, where the time period is a function of the combination of temperature and pressure. In this second vacuum treatment, water vapor and solvents absorbed during the development process are desorbed from surfaces of the patterned resist, including the sidewalls and top

resist surface. During desorption of the volatile components, the portion of the resist which is close to the surface is placed in tension. It is theorized, but not intended as a limitation, that this surface tension may allow for the "pulling together" of the surface, which may smooth out sidewall roughness. Since the bulk of the resist (deeper than within a few nanometers of the surface) is not in tension, lines and other features are not distorted.

[0020] The vacuum treatment processes of the invention work well whether the photoresist on the photomask substrate has been exposed to electron beam (e-beam) or optical radiation. Vacuum processing of photomask substrates according to the method of the invention typically improves the mean CD of the patterned photoresist by reducing the variation from the intended CD by about 3 nm or more, and by improving the uniformity (3-sigma) across a substrate surface by about 3 - 5 nm.

[0021] **BRIEF DESCRIPTION OF THE DRAWINGS**

[0022] Figure 1A shows a schematic cross-sectional view of a typical embodiment of a beginning structure 100 of a stack of materials used in the production of a photomask or reticle, when the pattern is transferred from the photoresist to the radiation-blocking layer of the mask without the use of a hard mask. The stack from bottom to top includes a substrate 102, which is typically selected from quartz, fluorinated quartz, borosilicate glass, or soda lime glass; a radiation-blocking layer 104, which is typically a metal-containing layer selected from a chromium, molybdenum silicide, or tungsten-containing layer, or combinations thereof (in the examples described herein, the radiation-blocking layer is essentially chrome); an inorganic ARC layer 105; an organic ARC layer 106; and a photoresist layer 108.

[0023] Figure 1B shows the Figure 1A structure 100 after development of the photoresist layer 108 to create a pattern of lines and spaces in the photoresist layer 108.

[0024] Figure 2 is a graph 200 showing a global cross 1 x CD uniformity (in nm) following vacuum treatment of the imaged photoresist prior to development, when the substrates were vacuum treated in a MEBES™ QUADRA™ imaging system ("RSB Vacuum") or were vacuum treated in an Applied Materials' TETRA™ etch chamber ("Tetra Vacuum"), compared with the global CD uniformity for substrates which received no vacuum treatment following exposure of the photoresist to radiation ("No Vacuum").

[0025] Figure 3 is a graph 300 showing the decrease in developed photoresist thickness 302 as a function of time under vacuum 304, for photomask substrates which were vacuum treated in accordance with the present invention. The substrates were vacuum treated in an Applied Materials' TETRA™ etch chamber, at a temperature of approximately 45°C and a process chamber pressure of approximately 0.5 mTorr.

[0026] Figure 4 is a graph 400 showing local CD uniformity (in nm) before and after vacuum treatment of the developed photoresist. The substrates were vacuum treated in an Applied Materials' TETRA™ etch chamber for a period of 20 minutes, at a temperature of approximately 30°C and a process chamber pressure of approximately 1 mTorr.

[0027] **DETAILED DESCRIPTION OF THE INVENTION**

[0028] We have discovered a method of improving the patterning of a layer of photoresist which has been applied over a photomask substrate, The present method results in improved critical dimension uniformity of the developed photoresist. In general, the method comprises the steps of: a) post-apply baking the photoresist; b) exposing the photoresist to imaging radiation (typically direct-write radiation); c) exposing the imaged photoresist to a vacuum for a period of time sufficient to allow pattern critical dimensions to equilibrate across the photoresist, at a process chamber pressure ranging from about 5×10^{-6} mTorr to about 5 mTorr (typically, at a temperature ranging from about 20°C to about 60°C, and for a time period ranging from about 10 minutes to about 70 hours);

d) post-exposure baking the imaged photoresist; and e) developing the imaged photoresist to create a pattern having openings through the photoresist layer thickness.

[0029] The method may further comprise the additional step f) of exposing the developed photoresist to a vacuum subsequent to step e), at a substrate temperature within the range of about 20°C to about 60°C for a period of time within the range of about 10 minutes to about 60 minutes, at a process chamber pressure ranging from about 5×10^{-6} mTorr to about 5 mTorr. This second vacuum exposure step has been shown to improve the line edge roughness of pattern openings that have been formed through the photoresist layer thickness.

[0030] As a preface to the detailed description presented below, it should be noted that, as used in this specification and the appended claims, the singular forms "a", "an", and "the" include plural referents, unless the context clearly dictates otherwise.

[0031] I. METHOD OF PATTERNING A PHOTORESIST ON A PHOTOMASK SUBSTRATE

[0032] All methods of patterning a photomask substrate may benefit from application of the present method. The method is particularly useful for DUV optical or e-beam patterning of a photomask when a chemically amplified photoresist is used to transfer the pattern to the photomask. The present Examples are for a REAP™ 200 chemically amplified photoresist (available from Tokyo Ohka Kogyo Co., Ltd. (TOK), Kawasaki, Japan), which is useful with both e-beam radiation and 248 nm optical radiation. However, the scope of the invention is not intended to be limited to this family of chemically amplified photoresists.

[0033] Figure 1A shows one embodiment of a starting structure 100 used in the fabrication of example photomasks for experimental purposes herein. In this Example, starting structure 100 was a stack of layers (not shown to scale) which included, from top to bottom, a 3000 Å thick layer 108 of a chemically amplified photoresist, REAP™ 200 (available from TOK, Kawasaki, Japan); a 500 Å thick layer 106 of an organic ARC identified as XLT-BARC (available from Brewer Science, Inc., Rolla, MO); a 300 Å thick layer 105 of chromium oxynitride inorganic ARC; a 400 Å thick layer 104 of chrome mask

material; and a silicon oxide-containing substrate 102.

[0034] The starting structure 100 shown in Figure 1A can be formed using conventional deposition techniques known in the art of semiconductor manufacture. In particular, the photoresist layer 108 is typically applied to the surface of the organic ARC layer 106 using spin-on coating techniques. Some of the solvent or dispersion medium is removed during the spin coating operation.

[0035] Photoresist compositions of the kind suitable for use in the present method include: REAP™ 200 and EN24 (both available from TOK, Kawasaki, Japan); NEB 22 (available from Sumitomo Chemical Co., Ltd., Tokyo, Japan); and FEP 171 and FEN 270 (both available from Fuji-Hunt Electronics Company, Tokyo, Japan), by way of example and not by way of limitation.

[0036] After application of the photoresist layer, applicants performed a post-apply bake (PAB) process to remove residual solvent or dispersion medium. The post-apply bake process is typically performed at a temperature within the range of about 70°C to about 150°C, for a time period of about 4 minutes to about 30 minutes. A particularly useful post-apply bake process is described in detail in U.S. Patent No. 6,703,169, to Fuller et al., the disclosure of which is incorporated by reference in its entirety.

[0037] After post-apply bake, the photoresist was exposed to radiation (imaged), to produce a latent pattern in the photoresist layer, typically by a direct write process when the pattern includes dimensions which are less than about 0.4 μm. In the example embodiment, the minimum pattern dimension was about 60 nm. In the exposure process, the integrated circuit patterns were direct written onto the unpatterned photoresist 108 coated on a mask blank which included organic ARC layer 106, inorganic ARC layer 105, chrome-containing layer 104, and quartz layer 102 (described above). In a different embodiment, a hard mask (not shown) may be present between the photoresist 108 and the radiation-blocking layer 104.

[0038] The vacuum treatment process of the invention works well whether imaging of the photoresist is by e-beam radiation or by optical radiation. In the examples described

herein, imaging of the photoresist was performed in a MEBES™ QUADRA™ electron beam mask patterning system (available from ETEC Systems, Inc., an Applied Materials company, with Applied Materials, Inc., having offices in Santa Clara, CA). Other imaging systems which can be used to practice the method described herein include, without limitation, the MEBES™ eXara™ electron beam mask patterning system, and the ALTA™ 3900 and ALTA™ 4300 laser beam mask patterning systems (all available from ETEC Systems, Inc.).

[0039] After imaging of the photoresist on the photomask substrate, the imaged photoresist was treated with a vacuum for a period of time sufficient to allow pattern critical dimensions to reach equilibrium across a given photoresist layer. The time period required for latent, imaged pattern critical dimensions to reach equilibrium across the photoresist will depend upon a combination of the temperature of the substrate during the vacuum treatment process and the pressure (vacuum) applied. After exposure of the imaged photoresist on the photomask substrate to vacuum for an optimum time period, no substantial change in pattern critical dimensions will occur upon continued exposure of the imaged photoresist to vacuum.

[0040] Typically, the higher the temperature, the less time is required for imaged pattern critical dimensions to reach equilibrium. However, the temperature is limited by the general stability of the photoresist material, which will depend on the particular photoresist material used. Also, typically the lower the pressure in the process chamber, the less time is required at a given temperature; however, the pressure used must ensure that deformation of the pattern does not occur and that the integrity of the photoresist is preserved. The amount of time required will also depend upon the condition of the photoresist prior to the vacuum treatment process, which will depend upon the type of photoresist used, the solvents in the photoresist, and the length of time of the post-apply bake (PAB) process. With minimal experimentation, one skilled in the art will be able to determine the amount of time required based on the particular apparatus that s/he is using and the particular process conditions under which that apparatus typically operates.

[0041] Vacuum treatment of photomask substrates in accordance with the methods of the invention can be performed in any suitable semiconductor processing apparatus which is capable of maintaining a process chamber pressure within the range of about 5 x 10^{-6} mTorr to about 5 mTorr. For example, an imaged photomask substrate may be vacuum treated in the exposure tool used for direct-write pattern irradiation of the photoresist. Alternatively, vacuum treatment of the imaged photomask substrates can be performed in other available equipment, for example, and not by way of limitation, in an Applied Materials' TETRA™ photomask etch system. By moving the photomask substrates to a different chamber for vacuum treatment following imaging, exposure tool throughput is not affected.

[0042] Typically, exposure of the imaged photoresist on the photomask substrate to vacuum is performed at a substrate temperature within the range of about 18°C to about 60°C (more typically, within the range of about 18°C to about 40°C. Heating of the imaged resist on the photomask substrate to a temperature within the range of about 30°C to about 60°C, and at a pressure ranging from about 0.1 mTorr to about 5 mTorr provides a substantial improvement in imaged resist pattern uniformity after a treatment.

[0043] Figure 2 is a graph 200 showing global cross 1 x CD uniformity 202 (in nm) following vacuum treatment of the imaged photoresist prior to development, where the substrates were vacuum treated in the MEBES™ QUADRA™ imaging system ("RSB Vacuum") 204 or were vacuum treated in an Applied Materials' TETRA™ etch chamber ("Tetra Vacuum") 206, compared with the global CD uniformity for substrates which received no vacuum treatment following exposure of the photoresist to radiation ("No Vacuum") 208. The RSB Vacuum substrates were vacuum treated in the pattern writing apparatus for a period of 5 - 9 hours at approximately 21 - 22°C), at a process chamber pressure of approximately 1 x 10^{-5} mTorr. The Tetra Vacuum substrates were vacuum treated in a TETRA™ etcher for a period of 30 minutes at a temperature of approximately 30°C, at a process chamber pressure of approximately 1 mTorr The substrates which received no vacuum treatment were maintained at approximately 21 - 22°C.

[0044] After vacuum treatment, the photoresist was baked again. The second baking step is typically referred to as a "post-exposure bake" or PEB.. Chemical reaction takes place between the time the pattern is written by irradiation upon the photoresist and the PEB, but after the PEB, the latent image is essentially fixed within the photoresist. The amount of time and the temperature of the substrate (*i.e.*, the time / temperature profile) depends on the photoresist, and one skilled in the art can determine what this should be in view of the photoresist manufacturer's recommendations.

[0045] The post-exposure bake process is typically performed at a temperature within the range of about 70°C to about 150°C, for a time period of about 4 minutes to about 30 minutes. A particularly useful post-exposure bake process is described in detail in U.S. Patent No. 6,703,169, to Scott Fuller et al., the disclosure of which is incorporated by reference in its entirety.

[0046] After post-exposure bake, the photoresist is developed, either using a dry process or a wet process, to create the pattern having openings through the photoresist layer thickness. The photoresist in the present instance was developed using a puddle or spray develop process with a TMAH (2.38 weight % or 1.91 weight %) developer.

[0047] We have also discovered that exposure of the patterned (developed) photoresist to vacuum after development results in an improvement in the line edge roughness of pattern openings that have been formed through the photoresist layer thickness. Accordingly, after development of the photoresist, the method of the invention may further comprise an optional step of exposing the photoresist to a vacuum at a substrate temperature within the range of about 20°C to about 60°C for a period of time within the range of about 10 minutes to about 60 minutes, at a process chamber pressure ranging from about 5×10^{-6} mTorr to about 5 mTorr.

[0048] In this second vacuum treatment, water vapor and solvents absorbed during the development process are desorbed from surfaces of the patterned resist, including the sidewalls and top resist surface. During desorption of the volatile components, the portion of the resist which is close to the surface is placed in tension. It is theorized, but not

intended as a limitation, that this surface tension may allow for the "pulling together" of the surface, which may smooth out sidewall roughness. Since the bulk of the resist (deeper than within a few nanometers of the surface) is not in tension, lines and other features are not distorted.

[0049] Proper timing of the vacuum treatment process allows for desorption of water vapor, solvents, and other by-products of previous processing steps from the surface of the resist, and also enables acids within the resist to diffuse in such a way as to reduce line edge roughness. Desorption of materials from the resist was found to slightly decrease the thickness of the photoresist layer. In addition, a slight shrinkage of pattern dimension was observed in the lateral (photomask plane) directions. Overall, vacuum processing of photomask substrates according to the method of the invention typically improves the mean CD of the patterned photoresist by reducing the variation of the intended CD by approximately 3 nm or more, and by improving the uniformity (3 sigma) across the wafer by about 3 - 5 nm. Our data also show an improvement in local CD uniformity.

[0050] Figure 3 is a graph 300 showing the decrease in photoresist thickness 302 for a developed photoresist as a function of time under vacuum 304 for photomask substrates which were vacuum treated in accordance with the present invention. The "curve" 306 of resist change is observed to "flatten out" (*i.e.*, reach equilibrium) after about 20 minutes of vacuum treatment, after which no substantial change in pattern critical dimensions was observed upon continued exposure of the imaged photoresist to vacuum. The substrates were vacuum treated in an Applied Materials' TETRA™ etch chamber for a period of 20 minutes, at a temperature of approximately 45°C, and a process chamber pressure of approximately 0.5 mTorr.

[0051] The data presented graphically in Figure 3 is for the REAP™ 200 photoresist. Data were also obtained for the EN24 photoresist (available from TOK, Kawasaki, Japan) and FEP 171 photoresist (available from Fuji-Hunt Electronics Company, Tokyo, Japan), under the same processing conditions described above for the REAP™ 200 photoresist. These data are presented in Table One, below.

[0052] Table One. Decrease in Photoresist Thickness Following Post-Exposure Vacuum Treatment

Photoresist	Decrease in Photoresist Thickness (Å)
REAP™ 200	20
EN24	23
FEP 171	17

[0053] Figure 4 is a graph 400 showing local CD uniformity 402 (in nm) before ("PreVac CDU") and after ("PostVac CDU") vacuum treatment of the developed photoresist. The substrates were vacuum treated in an Applied Materials' TETRA™ etch chamber for 20 minutes, at a temperature of approximately 30°C and a process chamber pressure of approximately 1 mTorr. Local CD variations for the y direction pre-vacuum treatment 404 and post-vacuum treatment 406 are shown for a first sample ("Sample # 1"). Local CD variations for the y direction pre-vacuum treatment 408 and post-vacuum treatment 410, are also shown for a second sample ("Sample # 2"). The two photomask substrate samples had different line-and-space patterns, which would explain the variation in CD uniformity between the two samples. The data shown in Figure 4 are for a REAP™ photoresist (available from TOK, Kawasaki, Japan).

[0054] In addition to their use in the preparation of photomasks, the vacuum treatment processes described herein can be used to improve the quality of lithography in the patterning of semiconductor wafers. The vacuum treatment processes described herein can be applied to all wafer lithographic processes where critical dimension control is required, for all wavelengths of light utilized in wafer optical and e-beam lithography (G-line, i-line, KrF, ArF, 257 nm, for example, and not by way of limitation), plus other methods used for patterning resist on wafers, such as EUV. Line edge roughness is reduced, and critical dimension control is improved.

[0055] Figure 1B shows a schematic cross-sectional view of the patterned photoresist layer 108 (prior to transfer of the pattern through underlying organic ARC layer 106, inorganic ARC layer 105, and chrome-containing layer 104), where the pattern was lines 107 and spaces 111, where the line width was about 30 nm to about 3 μm and the spacing between lines was about 30 nm to about 3 μm.

[0056] Once the photoresist has been developed and "patterned", so that the pattern openings extend through the photoresist layer to the upper surface of an ARC layer, or to a surface beneath an ARC layer, subsequent processing steps are typically performed in order to transfer the pattern in the patterned photoresist through the chrome-based mask layer and any remaining layers overlying the chrome layer. These subsequent processing steps are summarized below and are also described in detail in U.S. Patent No. 6,703,169, to Scott Fuller et al., which is incorporated by reference herein in its entirety. The mask fabrication process transforms the latent image created by the exposure of the photoresist into a permanent chrome image on the quartz substrate.

[0057] The pattern in the photoresist is typically transferred to the underlying photomask structure using a dry etch process, such as a plasma etching process. The chrome oxynitride (inorganic ARC) / chrome mask layer etch is typically performed using a plasma generated from a chlorine / oxygen / helium gas mixture. Typically, higher oxygen concentrations and lower pressures cause higher mean-to-target deviation and lower selectivities, while favoring better CD uniformity control. Plasma etch systems such as the TETRA™ etch system (available from Applied Materials, Inc., of Santa Clara, CA) may be used to provide excellent results. However, one skilled in the art will be able to optimize the process for other plasma etch apparatus.

[0058] Typically, the chrome layer is overetched beyond endpoint to clear residual chrome from all open regions. Generally, the overetch step is an extension of the chrome etch process described above. Longer overetch steps result in higher mean-to-target deviations. Chrome spot defect densities can be affected by the length of overetch, with lower defect densities for longer overetch processes.

[0059] After completion of the chrome layer etch, a strip and clean process is typically performed to remove any residual contaminants from the surface of the chrome layer. The strip process may be performed by heating sulfur peroxide to about 75 °C and applying the heated sulfur peroxide over the surface of the substrate plate. After treatment with sulfuric peroxide, the substrate plate is typically rinsed with CO_2-reionized or CO_2-sparged deionized water. After strip, the substrate plate is typically subjected to an acid clean using an industry standard 70 : 30 H_2SO_4 / H_2O_2 solution, followed by another deionized water rinse. For example, the strip step may be performed on a Steag ASC 500 wet chemical processing station, available from STEAG-HAMMATECH® (Santa Clara, CA).

[0060] The above described preferred embodiments are not intended to limit the scope of the present invention, as one skilled in the art can, in view of the present disclosure, expand such embodiments to correspond with the subject matter of the invention claimed below.

[0061] **CLAIMS**

We claim:

1. In a method of patterning a layer of photoresist which has been applied over a photomask substrate and exposed to imaging radiation, the improvement comprising exposing said imaged photoresist to a vacuum for a period of time sufficient to allow pattern critical dimensions to equilibrate across said photoresist, at a process chamber pressure ranging from about 5 x 10^{-6} mTorr to about 5 mTorr.

2. A method in accordance with Claim 1, wherein exposure of said imaged photoresist to said vacuum is performed at a substrate temperature within the range of about 18°C to about 60°C, for a period of time within the range of about 10 minutes to about 70 hours.

3. A method in accordance with Claim 2, wherein exposure of said imaged photoresist to said vacuum is performed at a substrate temperature within the range of about 18°C to about 40°C, for a period of time within the range of about 20 minutes to about 12 hours.

4. A method in accordance with Claim 1, wherein said radiation is e-beam radiation.

5. A method in accordance with Claim 1, wherein said radiation is optical radiation.

6. A method in accordance with Claim 1, wherein exposure of said imaged photoresist to said vacuum is performed prior to the performance of a post-exposure bake process.

7. A method in accordance with Claim 1, wherein said exposure of said imaged photoresist to said vacuum is performed prior to development of said photoresist to create a pattern having openings through said photoresist layer thickness.

8. In a method of patterning a layer of photoresist which has been applied over a photomask substrate, exposed to imaging radiation, and developed to create a pattern having openings through said photoresist layer thickness, the improvement comprising exposing said developed photoresist to a vacuum at a substrate temperature within the range of about 20°C to about 60°C for a period of time within the range of about 10 minutes to about 60 minutes, at a process chamber pressure ranging from about 5 x 10^{-6} mTorr to about 5 mTorr.

9. A method of patterning a layer of photoresist which has been applied over a photomask substrate, comprising:

a) post-apply baking said photoresist;

b) exposing said photoresist to imaging radiation;

c) exposing said imaged photoresist to a vacuum for a period of time sufficient to allow pattern critical dimensions to equilibrate across said photoresist, at a process chamber pressure ranging from about 5 x 10^{-6} mTorr to about 5 mTorr;

d) post-exposure baking said imaged photoresist; and

e) developing said imaged photoresist to create a pattern having openings through said photoresist layer thickness.

10. A method in accordance with Claim 9, wherein exposure of said imaged photoresist to said vacuum is performed at a substrate temperature within the range of about 18°C to about 60°C, for a period of time within the range of about 10 minutes to about 70 hours.

11. A method in accordance with Claim 10, wherein exposure of said imaged photoresist to said vacuum is performed at a substrate temperature within the range of about 18°C to about 40°C, for a period of time within the range of about 20 minutes to about 12 hours.

12. A method in accordance with Claim 9, wherein said radiation is e-beam radiation.

13. A method in accordance with Claim 9, wherein said radiation is optical radiation.

14. A method in accordance with Claim 9, wherein said method further includes the following step:

f) exposing said developed photoresist to a vacuum at a substrate temperature within the range of about 20°C to about 60°C for a period of time within the range of about 10 minutes to about 60 minutes, at a process chamber pressure ranging from about 5 x 10^{-6} mTorr to about 5 mTorr.

15. A method of patterning a layer of photoresist which has been applied over a photomask substrate, comprising:

a) post-apply baking said photoresist;

b) exposing said photoresist to imaging radiation;

c) post-exposure baking said imaged photoresist;

d) developing said imaged photoresist to create a pattern having openings through said photoresist layer thickness; and

e) exposing said developed photoresist to a vacuum at a substrate temperature within the range of about 20°C to about 60°C for a period of time within the range of about 10 minutes to about 60 minutes, at a process chamber pressure ranging from about 5 x 10^{-6} mTorr to about 5 mTorr.

16. A method in accordance with Claim 15, wherein said imaging radiation is e-beam radiation.

17. A method in accordance with Claim 15, wherein said imaging radiation is optical radiation.

[0062] **ABSTRACT OF THE DISCLOSURE**

[0063] We have discovered that exposure of a photoresist on a photomask substrate to a vacuum after the photoresist has been exposed to imaging radiation results in improved critical dimension uniformity of the developed photoresist. Exposure of the imaged photoresist to vacuum is performed for a period of time sufficient to allow pattern critical dimensions to reach equilibrium across the photoresist. The vacuum treatment process of the invention is typically performed prior to the performance of a post-exposure bake process and prior to development of the photoresist. We have also discovered that exposure of a photoresist on a photomask substrate to a vacuum after the photoresist has been developed results in an improvement in the line edge roughness of pattern openings that have been formed through the photoresist layer thickness.

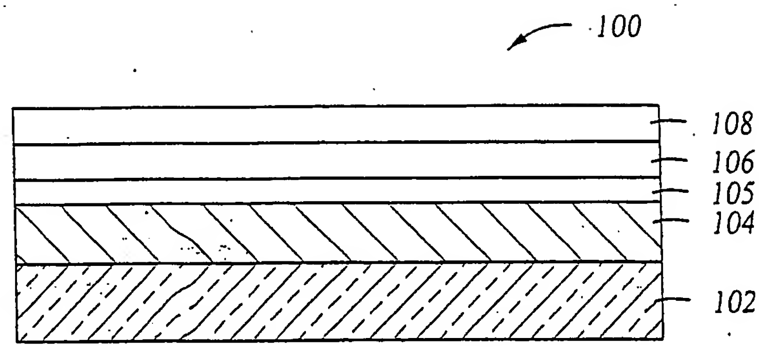


Fig. 1A
(Prior Art)

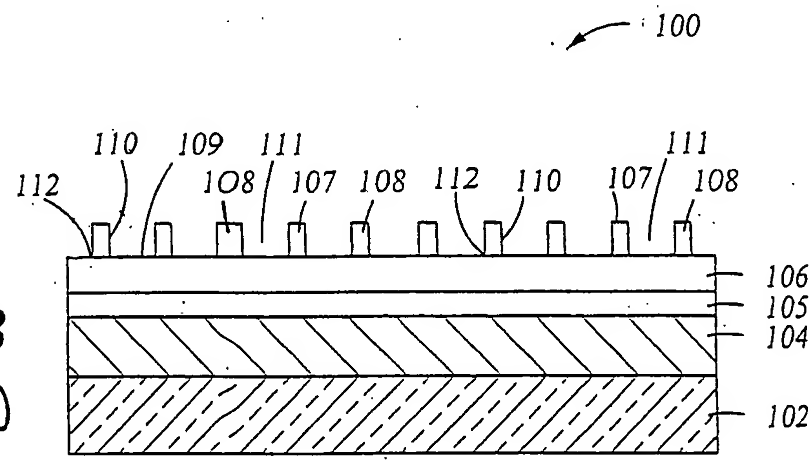
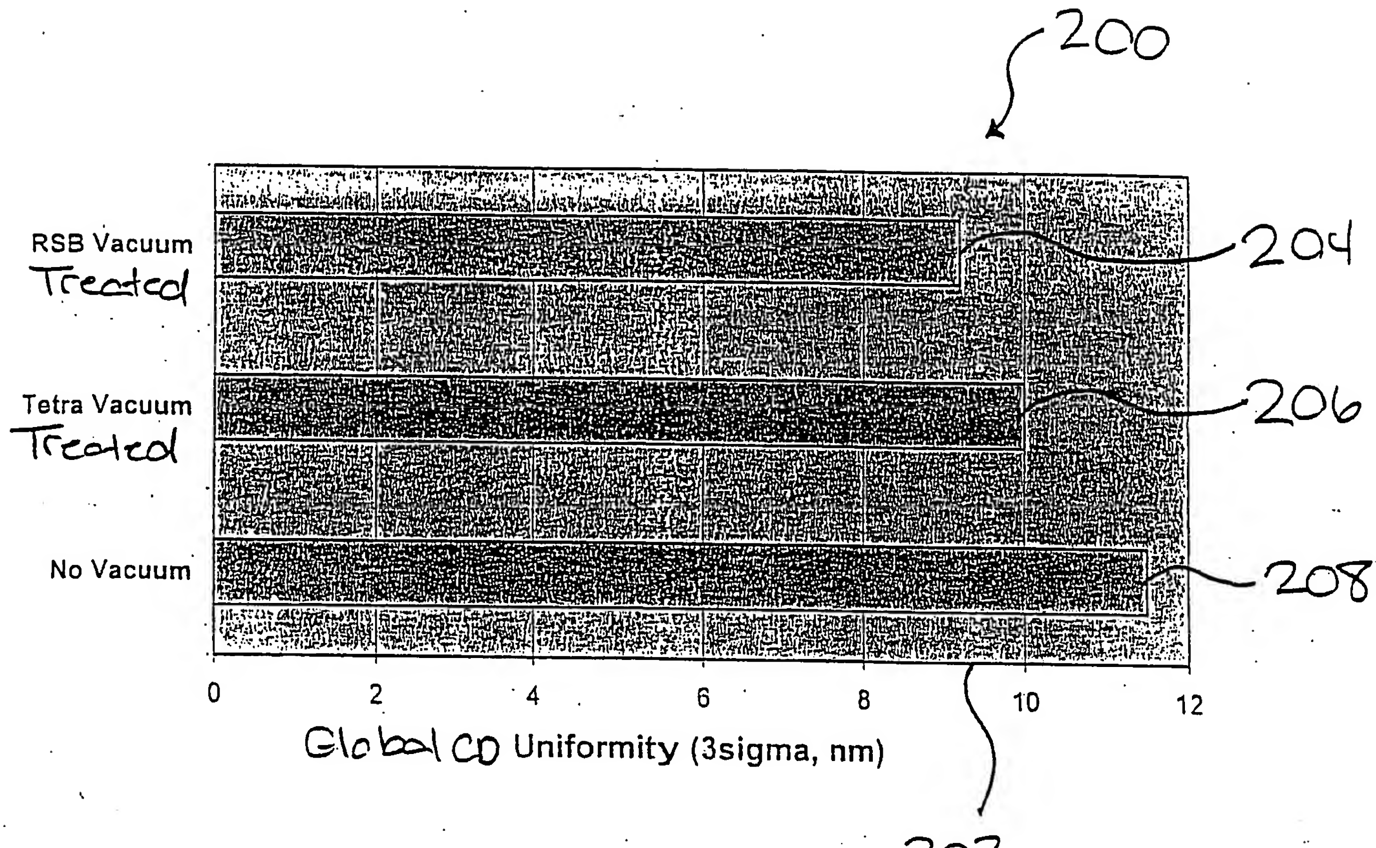


Fig. 1B
(Prior Art)



200
RSB Vacuum Treated
Tetra Vacuum Treated
No Vacuum
204
206
208
0
2
4
6
8
10
12
Global CD Uniformity (3sigma, nm)
202

Fig. 2

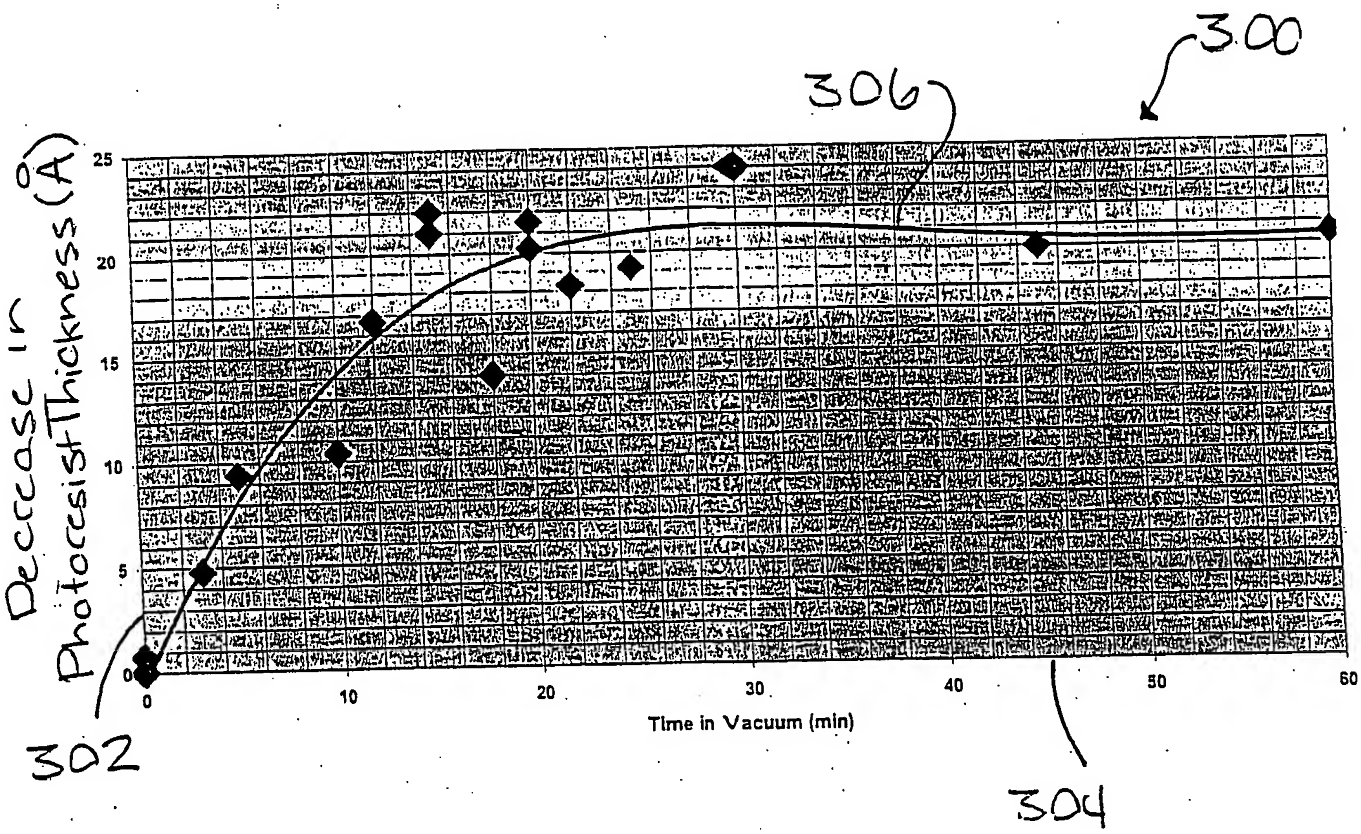
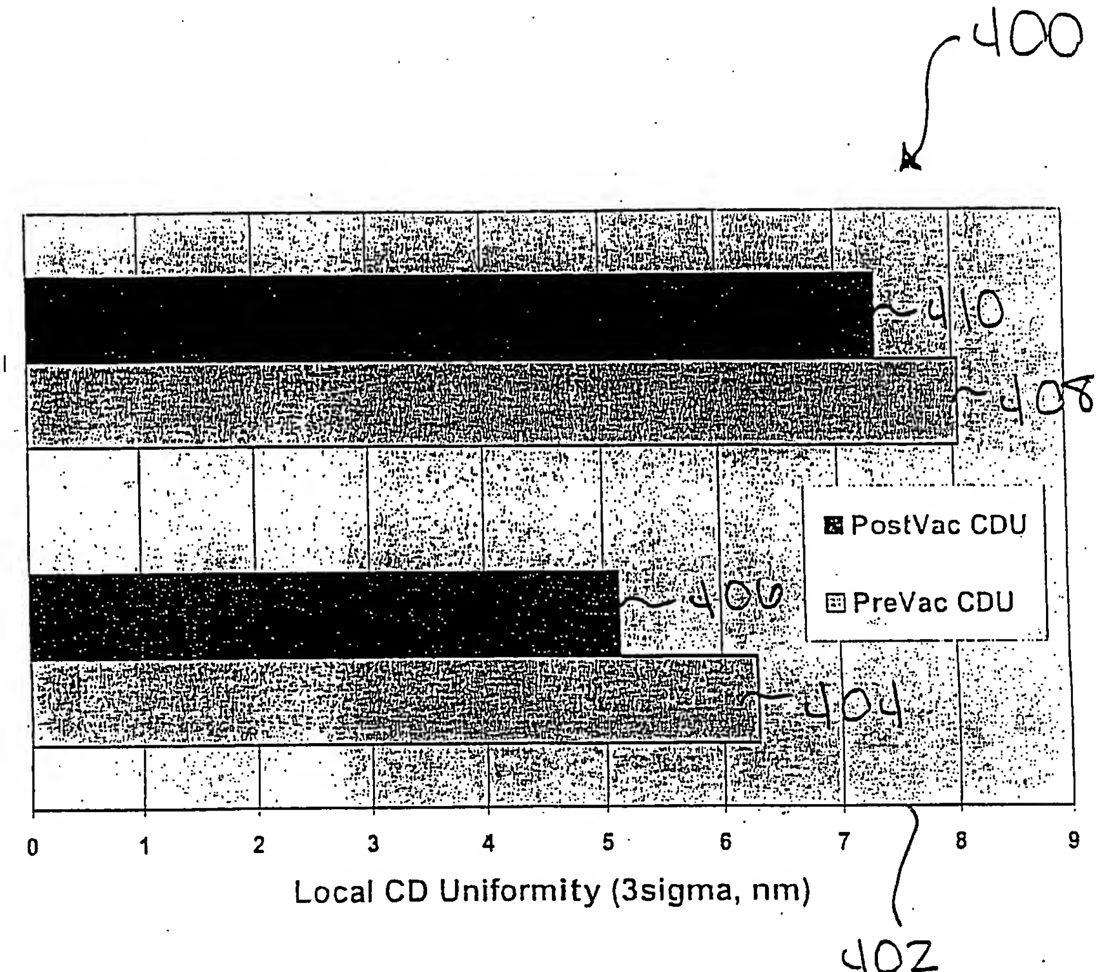

300
306
302
304
Decrease in Photoresist Thickness (Å)
Time in Vacuum (min)
0
5
10
15
20
25
0
10
20
30
40
50
60

Fig. 3



400
410
408
406
404
402
PostVac CDU
PreVac CDU
0
1
2
3
4
5
6
7
8
9
Local CD Uniformity (3sigma, nm)

Fig. 4

OIPE EAP 17 FEB 25 2008 PATENT & TRADEMARK OFFICE

Attorney Docket No. AM-8893 Y1 U.S. Express Mail No.: EB 998981707 US

IN RE APPLICATION OF: Ki-Ho Baik, et al.	§ GROUP ART UNIT: 1763
	§
SERIAL NO.: 10/817,140	§
	§ EXAMINER: B.L. Raymond
FILED: April 2, 2004	§
	§
FOR: METHOD OF IMPROVING THE UNIFORMITY OF A PATTERNED RESIST ON A PHOTOMASK	§ ATTORNEY DOCKET NO.:
	§ AM-8893 Y1

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Delivery Date: Mo. Day	Time: ☐ AM ☐ PM	Employee Signature

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